Jugular bulb desaturation during off-pump coronary artery bypass surgery

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Introduction
Cardiopulmonary bypass (CPB) is a routine element of cardiac surgery that results in a number of inevitable derangements. These include, but are not limited to, acute hemodilution, a systemic inflammatory response, and oxidative stress, as well as the activation of platelets and complement elicited by blood contact with the surface of the CPB circuit, which may lead to gaseous or particulate embolization [1–4]. Off-pump coronary artery bypass grafting surgery (OPCAB) could attenuate most of these events and has lately been introduced as a suitable alternative to circumvent these side-effects. While it may seem logical to assume that the elimination of CPB with OPCAB would reduce some of the cerebral injury associated with cardiac surgery, other mechanisms remain, and postoperative cognitive dysfunction is well documented in OPCAB patients [5–7].

Further, hemodynamic compromise due to manipulation of the heart by the surgeon has been associated with a significant decrease in jugular venous bulb oxygen saturation (SjO2) [8,9] which, in turn, has been associated with cognitive decline [10,11]. Thus, impaired cerebral perfusion during OPCAB surgery is being discussed as a possible contributor to cerebral injury [7].

Abstract
Purpose. Off-pump coronary artery bypass grafting surgery (OPCAB) frequently results in significant jugular bulb desaturation. Although jugular bulb desaturation during OPCAB may be associated with postoperative cerebral injury, routine jugular bulb oximetry appears to be invasive and expensive. We hypothesized that intraoperative hemodynamic compromise during OPCAB due to cardiac displacement is associated with jugular bulb desaturation which correlates with specific hemodynamic and physiological changes.

Methods. Hemodynamic and physiological data were measured at the following points: (1) before anastomosis of the coronary artery (baseline); (2) during anastomosis of the left anterior descending artery; (3) during anastomosis of the circumflex branch or posterior descending artery; and (4) after chest closure. Arterial, mixed venous, and jugular venous bulb blood gas analyses were performed serially.

Results. Jugular bulb desaturation (≤50%) frequently occurred during surgical displacement of the heart. Mixed venous oxygen saturation (SvO2), partial pressure of carbon dioxide (Paco2), and central venous pressure (CVP) showed a significant relationship with jugular bulb oxygen saturation (r = 0.45) by multivariate linear regression analysis. Multivariate logistic regression analysis also demonstrated that SvO2 ≤ 70%, Paco2 ≤ 40 mmHg, and CVP ≥ 8 mmHg were likely predictors of the occurrence of jugular bulb desaturation.

Conclusion. Changes in SvO2, and Paco2 were associated with jugular bulb oxygen saturation, and SvO2 ≤ 70%, Paco2 ≤ 40 mmHg, and CVP ≥ 8 mmHg had a significant odds ratio for jugular bulb desaturation. We suggest that achieving normal values of SvO2, Paco2, and CVP may be important to prevent cerebral desaturation during OPCAB.

Key words Jugular bulb · Oxygen saturation · Off-pump · CABG · Mixed venous oxygen saturation
cerebral oxygen imbalance. Therefore, we hypothesized that certain patterns in physiological parameters such as $S_{\text{vO}_2}$, $P_{\text{aCO}_2}$, and CVP are associated with jugular bulb desaturation during OPCAB surgery.

**Patients and methods**

Following institutional review board approval, written informed consent was obtained from 43 consecutive patients undergoing elective OPCAB surgery. Patients receiving dialysis, and those with arterial fibrillation and left ventricle ejection fraction less than 40% were excluded from this study. Anesthesia was induced by intravenous midazolam (0.1 mg·kg$^{-1}$) and fentanyl (10 $\mu$g·kg$^{-1}$), and vecuronium (0.15 mg·kg$^{-1}$) was given prior to tracheal induction for muscular paralysis. Anesthesia was maintained by continuous infusion of propofol (6 mg·kg$^{-1}·h^{-1}$) and fentanyl (4 $\mu$g·kg$^{-1}·h^{-1}$), and intermittently vecuronium was administered intravenously if needed. After induction of anesthesia, the radial artery was cannulated to monitor arterial blood pressure and sample arterial blood. A 5.5-French fiberoptic oximeter catheter (Opticath; Abbott Laboratories, North Chicago, IL, USA) was inserted retrogradely into the right jugular bulb for analysis of $S_{\text{vO}_2}$. The proper position of the tip of the catheter was confirmed by anteroposterior cervical spine fluoroscopy. The proper position is reached when the catheter tip is situated cranial to a line extending from the atlanto-occipital joint space and caudal to the lower margin of the orbit. A pulmonary artery catheter (OptiQ; Abbott Laboratories) was inserted via the right internal jugular vein for the sampling of mixed venous blood and to obtain and calculate hemodynamic parameters.

All surgical procedures were approached through a standard median sternotomy under general anesthesia. Before grafting to coronary arteries, 100 unit kg$^{-1}$ of heparin was administered to keep activated clotting time between 250 and 350 s, determined by ACT II (Medtronic, Minneapolis, MN, USA). During the left anterior descending artery (LAD) anastomosis, stabilization of the LAD was accomplished with an Octopus 4 Tissue Stabilizer (Medtronic). In the circumflex branch (CX) or posterior descending artery (PDA) anastomosis, the Octopus 4 Tissue Stabilizer and a Starfish 2, and a heart positioner (Medtronic) were used. To further assist in providing good presentation of the target arteries, especially in the CX or PDA anastomoses, patients were placed in the Trendelenburg position where the operating table was tilted down to a 5° to 10° angle. While the patient was in the Trendelenburg position, the position of pressure transducers was adjusted to the height of the heart. Intracoronary shunts (ANASTA-FLO; Edwards Life Science, Irvine, CA, USA), were used to maintain coronary flow. During the anastomosis, norepinephrine was administered as needed up to 0.1 $\mu$g·min$^{-1}·kg^{-1}$ to maintain mean arterial pressure of more than 60 mmHg.

Hemodynamic data including mean arterial blood pressure (MAP), heart rate, CVP, mean pulmonary artery pressure (MPAP), and cardiac index (CI) were recorded, and arterial, mixed venous, and jugular venous bulb blood gas analyses were performed with the ABL720 (Radiometer Medical, Brønshøj, Denmark) at the following points: (1) before anastomosis of the coronary artery; (2) during anastomosis of the LAD; (3) during anastomosis of the CX or PDA; and (4) after chest closure. Blood samples and hemodynamic data were obtained after sufficient hemodynamic stability was obtained at each point. Nasopharyngeal temperature was also monitored, with a Mon-a-therm 12-French temperature probe (Mallinckrodt, Hazelwood, MO, USA) and recorded as body temperature (BT).

To compare any differences of hemodynamic variables at the four selected time points, one-way analysis of variance with repeated measures was used, followed by Tukey and Kramer tests as a post-hoc analysis. To assess an association between $S_{\text{vO}_2}$ and intraoperative variables, including CVP, cerebral perfusion pressure (CPP: MAP − CVP), MAP, MPAP, $S_{\text{vO}_2}$, $P_{\text{aCO}_2}$, nasopharyngeal temperature, and CI, simple linear regression analysis based on univariate analysis was performed. Variables related to lower $S_{\text{vO}_2}$ on univariate analysis with $P < 0.10$ were entered into a multivariate linear regression analysis. Further, another univariate analysis was performed with a $\chi^2$ test to assess the risk of jugular bulb desaturation. Physiological and hemodynamic variables were dichotomized as normal, or abnormal and then entered into a logistic regression analysis model. Also, as Polonen et al. [18] have demonstrated that a drop in $S_{\text{vO}_2}$ of less than 70% was associated with poor prognosis after cardiac surgery, and as a CI of less than 2.2 l·min$^{-1}·m^2$ has been used as a definition of low cardiac output syndrome [19–21], we selected $S_{\text{vO}_2}$ of 70% and CI of 2.2 l·min$^{-1}·m^2$ as the cutoff values. Those variables with $P < 0.10$ were again entered into a multivariate logistic regression analysis; differences were considered significant at $P < 0.05$.

**Results**

Patient demographics are shown in Table 1. Although 43 patients were enrolled in this study, 4 patients were excluded because of failure to either cannulate the jugular vein or to place the tip of the jugular venous bulb catheter at the appropriate position. Table 2 shows the physiological data by arterial blood gas analysis. There was a slight but significant decrease in pH during